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An Acoustic Analysis of Double Articulations in Ibibio

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1. Introduction

This paper presents an acoustic analysis of the double articulated plosives in Ibibio. Ibibio is spoken by between one and two million people in extreme southeastern Nigeria and in part of western Cameroun (Kaufman 1968:1). It is classified by Greenberg (1970:9) as a Cross-River language in the Benue-Congo branch of the Niger-Congo family. The name Ibibio, or Ibibio-Efik, as it is referred to by Greenberg, is applied to a group of dialects which for the most part are mutually intelligible, including Ibibio, Efik, Anang, Eket, Ibeno, and Andoni.

Of these dialects Efik has received the most attention in the literature. Few linguistic treatments of the remaining dialects exist, according to Kaufman. In her dissertation, she lists six vowel phonemes: /i, e, a, ɔ, o, u/. The phonemic consonant system appears in Figure 1.

Figure 1. Consonantal Phonemes (after Kaufman 1968:15).

p	t		k
b	d		
f	s		
m	n	ñ	ŋ
		y	w

In addition she lists two vocalic, three consonantal, and one quantity marker as secondary morphophonemes. The typical syllable canon is CV.

Ibibio is a tone language characterized by the terrace level effect. In this paper I use the grave accent [`] and the acute accent [´] to indicate low and high tones, respectively. If two phonemically high tones occur in the same word, only the first is marked in the phonetic transcription. The second of two acute accents indicates a high tone followed by downstep.

The phonetic realization of the voiceless bilabial plosive phoneme /p/ is of particular interest here. The phoneme /p/ is realized as the double-articulated labial-velar [k͡p] after a pause or juncture according to Kaufman (1968:44-5), e.g. the word ípá 'whip' is phonetically [ík͡pa]. Thus, according to her analysis the double articulation [k͡p] only appears as an allophone of /p/ in a somewhat limited environment; it never appears in final position, for instance.

Determining the acoustic characteristics of the labial-velar presents an interesting problem for the locus theory. According to this theory, place of articulation is detected mainly by transitions of the second formant. The actual locus is at a hypothetical frequency, which serves as the apparent source of the adjacent transitions. Generally, loci for bilabial consonants have been determined to be relatively low in frequency, ca. 700 Hz., while loci for alveolars are intermediate, ca. 1800 Hz., and those of velars are usually the highest, ca. 3000 Hz. (cf. Delattre, et al., 1955:771). However, the precise loci for velars have been rather difficult to determine and are influenced to a great extent by the frequencies associated with adjacent sounds (cf. Green 1969 and references therein).

The research which led to the formation of the locus theory was carried out primarily in English, a language which lacks double articulated plosives. The question is--what is the locus for labial-velar plosives--is it similar to the locus of labials, of velars, or does it have a unique locus? It is the specific purpose of this study to determine the distinctive acoustic characteristics of the labial-velars as opposed to simple labial or velar plosives, and to investigate their properties.

2. Method

The corpus consists of a tape-recording of a randomized list of 35 words read in isolation by a native speaker of Ibibio, a student at Ohio Wesleyan University. The recording was made by means of an Ampex microphone and Ampex 354 tape-recorder using Tenzar 175 tape at 7 1/2 i.p.s. in an Eckel Industries An-eck-oic chamber. The tape was processed using Frøkjær-Jensen Pitch and Intensity meters and displayed by an Elema-Schönander Mingograf. Wide band spectrograms were made on a Voiceprint 700, sections on a Kay Sona-Graph, 6061-A. The acoustic analysis is based on measurements made from the resulting duplex oscillograms, frequency and intensity curves, spectrograms, and sections. Principles of segmentation are based on standard techniques (Naeser 1970, Garnes to appear). All duration measurements are based on the mean of five productions, rounded off to the nearest ms. Frequency measurements are rounded off to the nearest 5 Hz.

3. Results

The results indicate that the double articulated plosives in Ibibio differ from simple plosives in three respects: (1) in phonation and voice onset time, (2) in the frequency of the burst which occurs at release, and (3) in transitions and locus. However, certain similarities also exist--these will be presented as the results are discussed.

3.1. Phonation and voice onset time. The double articulation [k͡p] consists of three distinct phases when it occurs in intervocalic position. These phases are (1) an onset, (2) the plosive gap, and (2) a voiced release. Simple plosives on the other hand have only the two expected phases: plosive gap and release. Voiceless plosives are characterized by an absence of energy during the plosive gap followed by a voiceless release, while the voiced plosives are voiced throughout, followed by a very brief voiced release. These relationships are illustrated by the repr-sentative words: [ák͡pa] 'the open sea', [àká] and [àbák] which are both names of towns, cf. Figure 2. Durations appear in Table 1. Representative mingograms of the three plosive types appear in Figure 3 showing the fundamental frequency (Fo), duplex osciologram (DO) and intensity curve (I).

Figure 2. Duration of double articulation [k͡p], voiceless plosive [k] and voiced plosive [b].

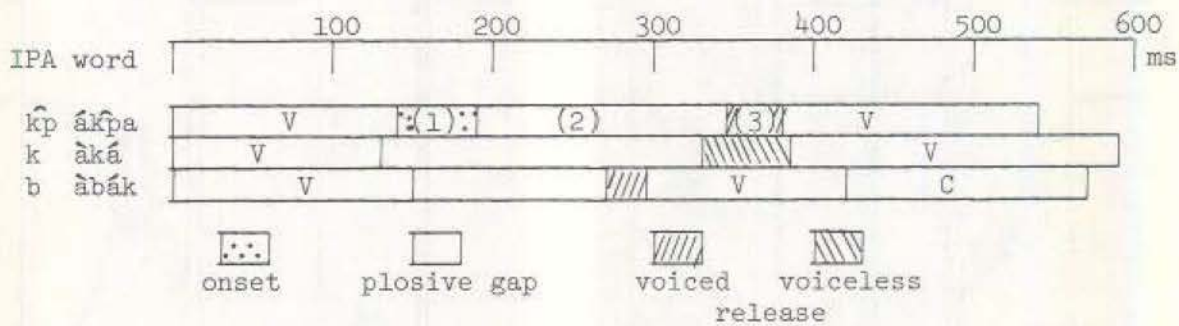
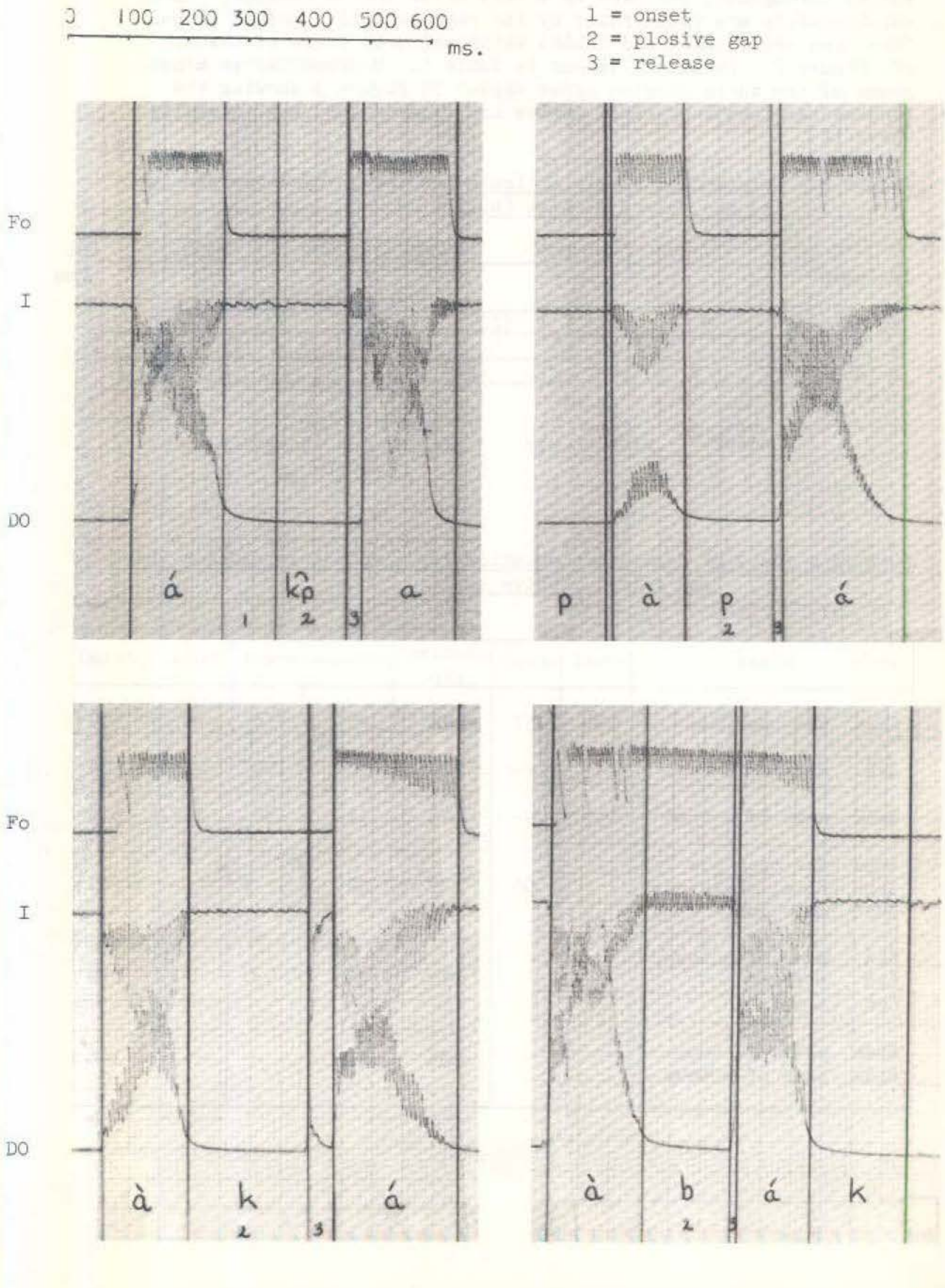


TABLE 1

Durations (ms.) of double articulation [k͡p], voiceless plosive [k] and voiced plosive [b].

word	gloss	vowel	onset	plosive gap	release	vowel	(cons.)	total
ákpa	the open sea	138	57	172	25	158	--	550
àká	name of a town	137	--	220	38	199	--	594
àbák	name of a town	148	--	142	11	130	147	578
ákpa ɔ̀k͡pɔ ɔ̀kpɔ́	the open sea bone, skeleton male goat		60	179	22			261
àká ɔ̀kɔ́ ɔ̀kɔ̀	name of a town a fence a pot			210	39			249
ábák àbák	palm oil soup name of a town			135	11			146

Figure 3. Fundamental frequency (Fo), intensity (I) and duplex oscillogram (DO) curves illustrating double articulation [k͡p], voiceless plosives [p], [k] and voiced plosive [b].



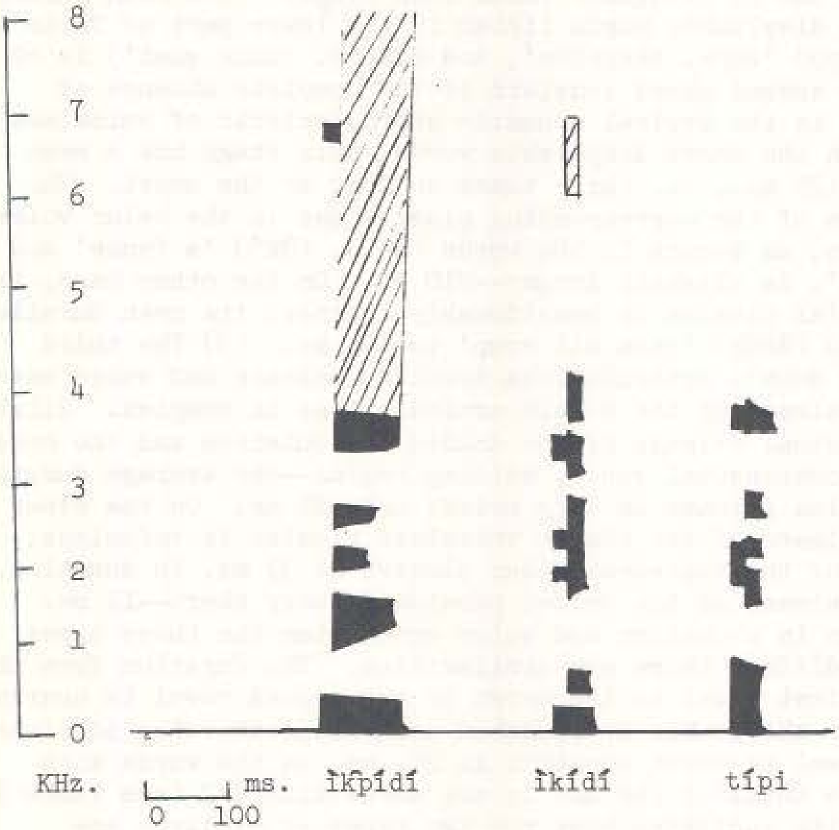
The three phases of the double articulation [k͡p] have distinct properties: (1) the first phase of the double articulation occurs at the cessation of the regular vowel oscillations. It is characterized by irregular, aperiodic low frequency vibrations which may be due to irregular vocal fold flaps.[1] Its mean duration in the three disyllabic words listed in the lower part of Table 1 ([ákpa], [ɔ̃kpɔ] 'bone, skeleton', and [ɔ̀kpɔ̃], 'male goat') is 60 ms. (2) The second phase consists of the complete absence of energy which is the typical acoustic characteristic of voiceless plosives. In the three disyllabic words, this stage has a mean duration of 179 ms., ca. three times as long as the onset. The mean duration of the corresponding plosive gap in the velar voiceless plosives, as occurs in the words [àká], [ɔ̃kɔ̃] 'a fence' and [ɔ̀kɔ̀] 'a pot', is slightly longer--210 ms. On the other hand, the voiced bilabial plosive is considerably shorter; its mean duration in [àbák] and [ábák] 'palm oil soup' is 135 ms. (3) The third stage of the double articulations involves release and voice onset time. The release of the double articulations is complex. Slightly before the actual release of the double articulation and the onset of the post-consonantal vowel, voicing begins--the average duration of voicing plus release is very brief; only 22 ms. On the other hand, the release of the simple voiceless plosive is voiceless; the release of the voiceless velar plosive is 39 ms. in duration.[2] The voiced release of the voiced plosive is very short--11 ms.

Although in phonation and voice onset time the three types of plosives differ, there are similarities. The duration from the end of the first vowel to the onset of the second vowel is nearly identical for the double articulated and voiceless velar plosives. The total vowel to vowel duration is 261 ms. in the words with [k͡p] versus a total of 249 ms. in the words with [k] (see Table 1). This similarity indicates that the two types of plosives are programmed similarly and provides evidence that the double articulation constitutes a single unit of timing.

3.2. Frequency analysis.

3.2.1. Bursts. A frequency analysis of the plosive bursts was obtained by making sections during the final portion of the plosive gap and the release of the double articulations and the voiceless plosives. Schematic diagrams of these sections appear in Figure 4. Distinctly different patterns emerge. In the word [ìk͡pídí] 'if we would come' the release of the labial-velar has an initial concentration of energy at 6500 Hz.immediately followed by concentrations of energy centered at 1200, 2000, 2400, and 3500 Hz. Weak energy is found throughout the frequencies above 3600 Hz. during the release.

Figure 4. Schematic diagrams illustrating frequencies of [k͡p], [k], [p] bursts.



The burst of the velar plosive in [ìkídí] 'as we arrived' has initial concentrations of energy centered at 1900, 2500, and 3500 Hz. In addition the velar plosive has weak concentrations of energy between 6000-7000 Hz., whereas the burst of the intervocalic bilabial plosive in [típi] (English loan word) has energy concentrated at 2000 and 3600 Hz. These measurements obtained here for the simple bilabial and velar voiceless plosives are similar to those found for [p] and [k] before high front vowels in English words as reported by Halle, Hughes and Radley (1956).[3]

In summary, the burst pattern of the double articulation [k͡p] differs in two distinct ways from that of the simple plosives: (1) both of the simple plosives have initial concentrations of energy at lower frequencies, whereas the double articulation lacks these lower frequency concentrations and has a high frequency burst, and (2) neither of the simple plosives has weak energy throughout the higher frequencies following the burst as does [k͡p].

3.2.2. Transitions. The transitions of the three points of articulation--bilabial, velar and labial-velar are distinctive, yet interrelated. Figure 5 gives the mean values of transitions in Hz.

and ms. from steady states of the vowels [e] and [ɔ] to and from the hubs for [b], [k], and [k͡p]. The measurements appear in Table 2; spectrograms of a set of words with [e] appear in Figure 6. For each place of articulation a different pattern obtains. The hubs for [b] are all negative, i.e. lower than the steady state. Thus, for the bilabial and the expected relationship obtains; the measurements indicate that the locus is low.

Figure 5. Transitions of [e]—and [ɔ]--in the environment of [b], [k] and [k͡p].

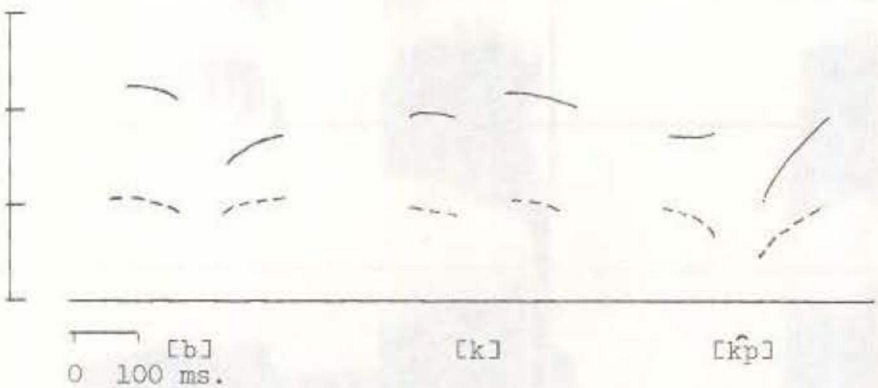
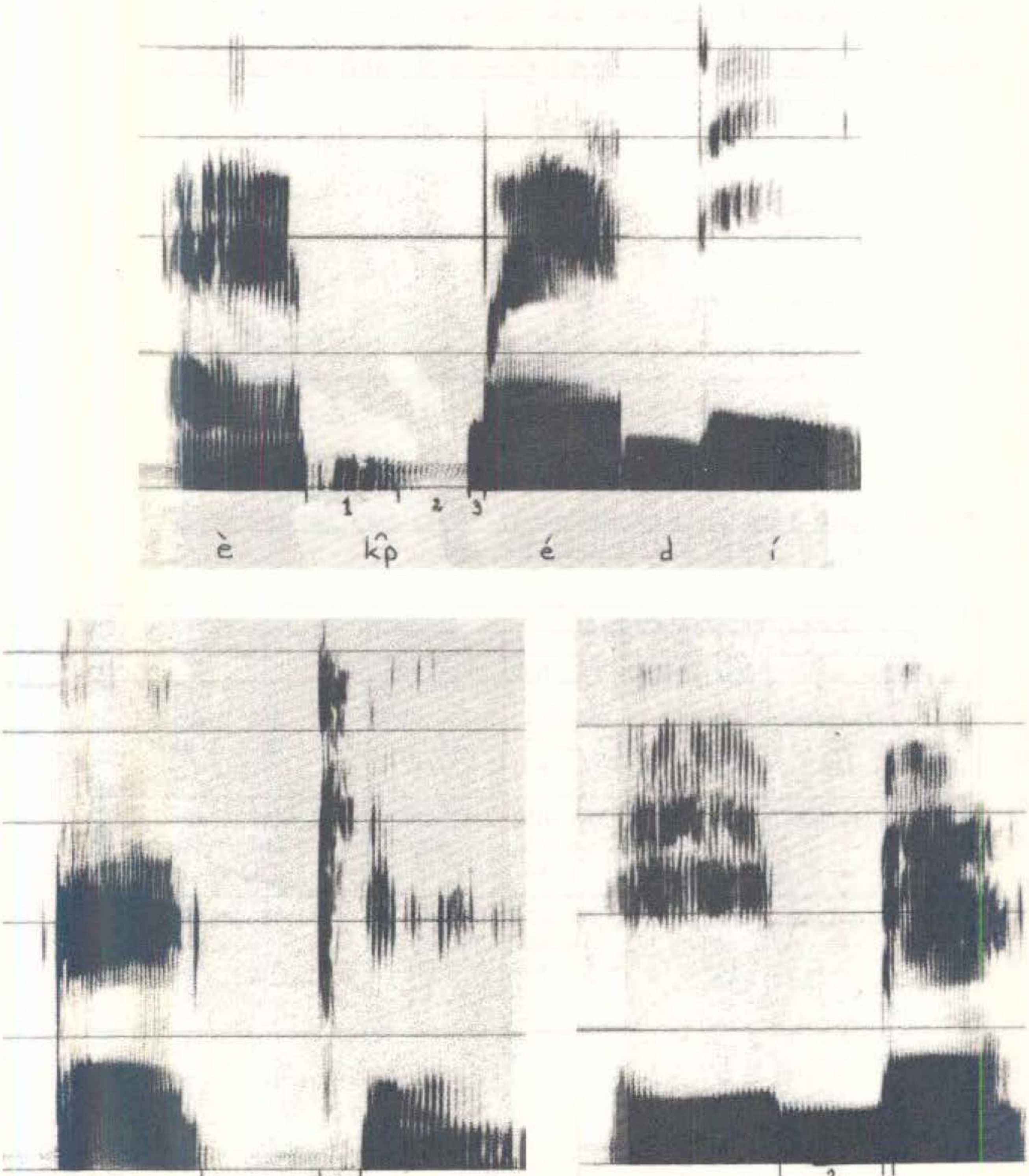


TABLE 2

Frequency and duration measurements of transitions between vocalic steady states (ss) and hubs

	Vowel [e] ss hub	Vowel [e] hub ss	Vowel [ɔ] ss hub	Vowel [ɔ] hub ss	Plosive Lexical Item
Hz. Dif. Ms.	2275-2185 -90 46	1450-1725 -275 61	1060-940 -120 68	915-1070 -155 65	[b] èbé 'husband' ɔ́bɔ́ŋ 'chief'
Hz. Dif. Ms.	1975-1950 -25 --	2190-2065 +125 72	990-880 -110 49	1065-980 +85 65	[k] ékè 'particle' ɔ̀kɔ́ 'a fence'
Hz. Dif. Ms.	1700-1735 +35 --	1000-1885 -885 68	960-980 -280 53	475-950 -465 56	[k͡p] èkpédí 'if they would come' ɔ̀kpɔ́ 'bone, skeleton'

Figure 6. Spectrograms illustrating double articulation [k͡p], voiceless plosive [k], voiced plosive [b].



The hubs for [k] do not form as symmetrical a pattern as those for [b]; the preconsonantal vowel transition is negative, whereas the transition for the postconsonantal vowel is positive. (The measurement extends from the onset of voicing to the steady state--no measurement was attempted during the voiceless release.) It is not unexpected that the velar transitions are asymmetrical (cf. Green 1959). However they are clearly different from those of the bilabial.

The transitions in the labial-velar environment also form a unique pattern. The preconsonantal transitions for the unrounded vowel [e] are nearly level and are more similar to those for the simple velar than for the bilabial, whereas the preconsonantal transitions for the rounded vowel [ɔ] are negative and steeper than those for the bilabial. The postconsonantal transition is negative and extremely steep--whereas the difference in the transition from the bilabial hub to the steady state of [e] is 275 Hz, the difference is 885 Hz. following the labial-velar. The transition is similar for rounded vowels also.

It is important to note the duration of the transitions. The transitions following the bilabial and labial-velar occur very rapidly (cf. Table 2). It might seem that with the greater frequency difference between the hub and steady state following the labial-velar, the duration of the transition would be longer. This does not happen, and indeed, if it did, the resulting perceptual effect would be characteristic of a different manner of articulation--a glide--rather than a plosive. The observed rapid transition is essential, and natural for the plosive manner of articulation.[4]

The answer to the primary question of this investigation--can the locus theory account for the labial-velar double articulation is affirmative--the labial-velar is characterized by distinctive transitions. At this point it is interesting to comment on the distribution of the labial-velar and the syllable canon of Ibibio. As mentioned in section 1, the labial-velar is always followed by a vowel. In initial position, where the characteristic onset of the intervocalic labial-velar is absent, the distinctive post-consonantal transition appears, as in [kpʊ̀p] 'make the noise (voiceless bilabial trill)'. If the labial-velar were to occur in final position it is questionable whether sufficient acoustic cues would be present to distinguish it from simple plosives.

4. Discussion

Ladefoged (1968) has investigated the double articulations in considerable detail as they occur in West African languages. He found three sub-types of labial-velars based on the airstream mechanism(s) used in their production. The pulmonic egressive air stream is used "in many Guanɔ languages (Late, Anum)". The other two types use additional air stream mechanism(s). The second type "is found in Yoruba, Ibibio and many other languages" (1968:9). It combines both the pulmonic and the velaric air stream mechanism (the latter is usually associated with clicks). Ladefoged describes it as follows:

After the two closures have been made, there is a downward movement of the jaw, and a backward movement of the point of contact of the back of the tongue and the soft palate; these movements cause a lowering of the pressure in the mouth. Thus, from the point of view of the release of the closure at the lips, there is an ingressive velaric airstream. But there is still a high pressure behind the velar closure owing to the outgoing air from the lungs (the pulmonic egressive airstream mechanism). Consequently when both closures are released the air flows into the mouth from two directions. This combination of a velaric and pulmonic airstream mechanism has been described very accurately by Siertsema...who concluded that Yoruba [kp] 'is implosive at the lips, "explosive" at the back'. Welmers...also states that in the case of Senadi: 'During the stop, there is noticeable suction in the oral cavity, with a resultant "pop" at the moment of release' (1968:9).

The third type includes the glottalic ingressive airstream (usually associated with implosives) in addition to the velaric and pulmonic air stream mechanisms. Ladefoged posits the presence of this third air stream mechanism based on evidence from oral and pharyngeal air pressure measurements and a microphone trace which indicates a brief period of voicing just before release of the plosive. (No spectrograms of the utterances are included.) It is interesting to note that for the Ibibio informant in this study, a brief period of voicing occurs before release of the labial-velar. It is possible that this voicing is due to a glottalic ingressive air stream in Ibibio, in which case Ibibio is incorrectly placed in the second classification above. However, the period of anticipatory voicing may be due to the release of the velar closure with air from the pulmonic egressive air stream rushing into the oral cavity. Clearly, if the term plosive is primarily associated with the pulmonic air stream, it is not sufficient to account for the double articulations discussed here which also appear to be intimately related to clicks and implosives.

Greenberg (1970) has noticed the connection between double articulations and implosives. He excludes the labial-velars from his study of glottalic consonants, although he presents evidence of a diachronic relationship between labial-velars and bilabial implosives.

5. Conclusion

In conclusion I want to stress that the results discussed here are based on one speaker and need to be submitted to further investigation. However, the analysis of the labial-velar double articulation indicates that it is timed similarly to simple plosives but contrasts with them in four ways: (1) voice onset time, (2) frequency and duration of burst and release, (3) locus, and (4) air stream mechanisms.

Contrastive acoustic analyses of implosives and clicks should prove enlightening in determining the classification of double articulations at the phonetic level. Such studies may provide additional insight into the distribution and historical development of double articulations.

Footnotes

[1]Although Ladefoged presents spectrograms in which low level aperiodic frequencies appear during the plosive gap of voiceless labial-velar double articulations (Itsekiri, plate 2A), he does not discuss that characteristic. The aperiodicity appears to correlate with a drop in oral air pressure, while pharyngeal air pressure is maintained. Ladefoged states that the drop in mouth pressure is due to the lowering of the jaw and the backward movement of the tongue (Ladefoged 1968:9).

Until air pressure measurements are made to determine the source and directionality of air-flow, it appears that for the Ibibio informant in this study, it is possible to hypothesize that the low frequency onset period of the intervocalic labial-velar is produced by air being forced downward by the backward movement of the tongue during the first portion of the closure.

It is important to note that there is no contrast between voiced and voiceless double articulations in Ibibio.

[2]The voiceless plosives have been analyzed (Kaufman 1968:44 ff.) as unaspirated. Her analysis is supported by the measurements found in this study.

[3]Halle, Hughes and Radley (1956:109) found that in productions of the words peel and keel by three speakers the energy density spectra were all strong below 1000 Hz. with those of [p] dropping off rapidly between 3000 and 4000 Hz. while greater energy was maintained for the velar plosive [k] up to 6000 Hz.

[4]Cf. Halle, Hughes and Radley (1956:116) who posit different feature detectors for consonants and vowels based in part on facts similar to those observed here.

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